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EFFECTS OF CORROSION ON MILITARY FACILITIES OF THE PRESIDIO OF --ETC(U)
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INTERIM REPORT M-254
August 1978
Corrosion Abatement Design Criteria

# EFFECTS OF CORROSION ON MILITARY FACILITIES OF THE PRESIDIO OF SAN FRANCISCO

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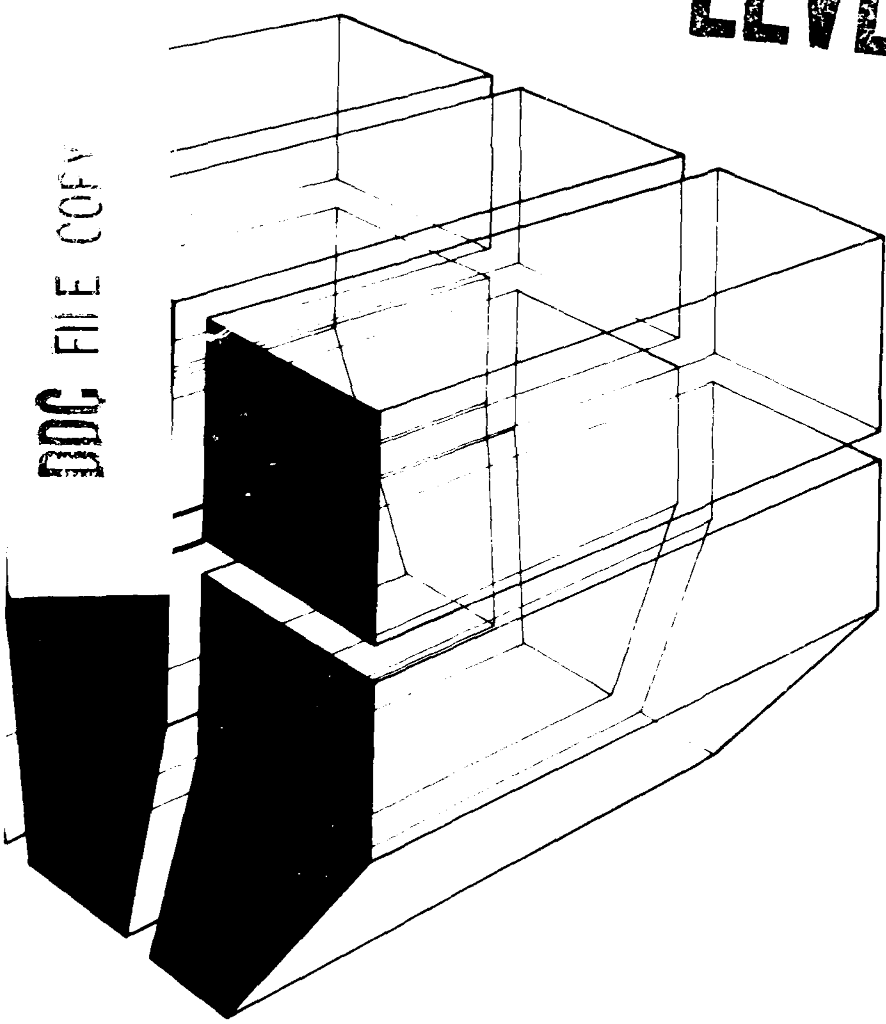

by
Christopher Hahin



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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

The effects of atmospheric corrosion on military facilities at the Presidio of San Francisco induced by airborne salt fall are described. Problem areas include deterioration of galvanized sheet metal, building hardware, refrigeration and air conditioning components, and exterior electrical distribution lines. Recommendations to decrease deterioration rates are made, along with suggested revisions to Technical Manuals 5-551K and 5-680C. An information exchange mechanism between design engineers (Corps of Engineers Districts) and maintenance engineers —

Block 20 continued.

(Facility Engineers) to improve facility longevity is proposed. Other measures to decrease life-cycle costs, consistent with military priorities, are also recommended.

## FOREWORD

This investigation was performed for the Directorate of Military Construction, Office of the Chief of Engineers (OCE), under Project 4A762731AT41, "Design, Construction, and Operations and Maintenance Technology for Military Facilities"; Task 7, "Materials for Military Construction"; Work Unit 001, "Corrosion Abatement Design Criteria." The applicable QCR is 1.03.007, "Parametrics of Corrosion." The OCE Technical Monitor is Mr. E. Hunt.

The study was performed by the Engineering and Materials Division (Dr. G. R. Williamson, Chief), U.S. Army Construction Engineering Research Laboratory (CERL).

Dr. L. R. Shaffer is Technical Director of CERL, and COL J. E. Hays is Commander and Director.

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CONTENTS

# EFFECTS OF CORROSION ON MILITARY FACILITIES OF THE PRESIDIO OF SAN FRANCISCO

## 1 INTRODUCTION

### Background

Corrosion results in a significant drain on the Army's real property resources. A study of Army and Air Force installations has indicated that 8 to 24 percent of real property maintenance expenditures are corrosion related, depending on local topography and climate.[1] Since corrosion rates are usually quite low, problems often appear long after the facility is built. Corrosion-induced failures may be caused by (1) improper design for the particular environment, (2) use of low-cost, but high corrosion rate materials, or (3) lack of normal preventive maintenance.

This report is part of an overall study of corrosion-related problems on military installations in various climatic zones in North and South America. The Facility Engineer organization and the Area Resident Engineer organizations are being analyzed to determine predominant corrosion problem areas, and to recommend research where the state of the art is inadequate. Changes to Technical Manuals (TMs) or Guide Specifications are recommended when necessary.

### Objective

The purpose of this part of the study was to analyze the deterioration of facilities and subcomponents in a temperate seacoast environment. System components having either favorable or unfavorable performance in this environment were specifically noted as being indicators of superior (and usually cost effective) or inferior construction over the long run. Maintenance or operational procedures which could increase facility life at less cost were also investigated.

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[1] C. Hahin, *Corrosion Costs of Air Force and Army Facilities and Construction of a Cost Prediction Model*, Technical Report 77-17 (Air Force Civil Engineering Center, 1977).

## Approach

The Presidio of San Francisco was selected as the study site for this environment. Supervisors of major work sections engaged in corrosion-related work were interviewed. Key engineers were contacted about maintenance and repair actions, including those accomplished in-house or by construction contract. Deteriorated components were examined, and corroded facilities and equipment were inspected. Corrosion problems were later analyzed to determine if existing technology or Army procedures could remedy the difficulty.

## Mode of Technology Transfer

Results of this study impact on TM 5-551K (AF TO 40P-1-131), *Plumbing and Pipefitting*, and TM 5-680C, *Overhead Distribution Systems*. (Recommended changes to these manuals appear in Appendices A and B, respectively.) Other TMs and Guide Specifications which may be affected are TM 5-810-1, *Heating, Ventilation and Air Conditioning;* TM 5-670, *Refrigeration, Air Conditioning, Mechanical Ventilation and Evaporative Cooling*, TM 5-625, *Sheet Metal;* TM 5-805, *Builder's Hardware;* TM 5-810-5, *Plumbing;* CE 251.01, *Builder's Hardware;* CE 301.36, *Central Refrigeration System;* and CE 303.7, *Aerial Electrical Distribution*.

## 2 ANALYSIS OF FINDINGS

### Economic Impact of Corrosion at the Presidio

The Annual Work Plan of the Presidio served as a basis for discussion with first-line supervisors about how their workers spent maintenance time. Each supervisor was asked to describe the nature of his segment of the Work Plan, and to estimate the percentage of each repair, maintenance, or replacement action that was related to metallic corrosion. Each job was evaluated by the following criteria:

1. Was the failure or deterioration of a metallic component corrosion-induced?

2. Did corrosion of a component result in damage to the building or its contents?

3. Was scale removed or scaled-up equipment replaced?

4. Was preventive maintenance, such as boiler water treatment or cathodic protection, performed to reduce corrosion losses?

Construction contracts from FY70 through FY75 were evaluated by the same criteria. Most of the corrosion-related work is confined to maintenance and repair contracts. Only one Military Construction-Army (MCA) project during the 6 year period analyzed was corrosion-related; a sewer replacement project for $209,600.

An analysis of the Annual Work Plan revealed that plumbers, sheet metal workers, heating mechanics, and exterior electricians spend a substantial amount of time on corrosion-related jobs. In terms of the Presidio's total operating budget (excluding Camp Parks and Troop Units), about 10.5 percent of all Facility Engineer expenses are related to corrosion. Similarly, about 8.9 percent of all construction contracts (non-MCA) stem from corrosion problems. Tables 1 and 2 contain a more detailed summary of these results.

### Corrosion Effects on Systems and Components and Recommended Solutions

*Plumbing Systems*

Deterioration of underground piping at the Presidio was caused by fairly low soil resistivity (ranges from 1,500 to 6,700 ohm-cm) and long burial times. Fixture replacement was confined to chrome-plated brass spouts and various zinc die-cast handles. The brass alloys failed because of general load-bearing section reduction caused by selective

Table 1

Summary of Facility Engineer Corrosion Costs for the Presidio[a]

| Work Section | % Corrosion-Related Work | Corrosion Cost[b] ($) | Total Operating Cost[b] ($) |
|---|---|---|---|
| Plumbing | 55.7 | 196,649 | 353,124 |
| Refrigeration | 20.3 | 41,210 | 400,106 |
| Heating Systems | 22.5 | 59,273 | 264,000 |
| Boiler Plant | 23.1 | 53,432 | 230,912 |
| Interior Electric | 9.3 | 30,144 | 325,000 |
| Exterior Electric | 22.4 | 51,296 | 229,000 |
| Water Plant | 12.2 | 26,039 | 214,060 |
| Woodworking | 12.6 | 59,184 | 468,000 |
| Metalworking | 33.5 | 41,850 | 125,000 |
| Painting | * | - | 155,000 |
| Roads and Pavements | 0.9 | 3,510 | 390,000 |
| Engineering Services | 8.9** | 56,797 | 638,175 |
| Preventive Maintenance | 10 (est) | 19,000 | 190,000 |
| Hospital Support | 4 (est) | 12,579 | 314,496 |
| Other Sections and Supervisory Overhead | - | - | 1,923,090 |
| | | 650,963 | 6,219,963 |

Overall Corrosion % = 10.5

[a]Excludes Camp Parks and Troop Units
[b]Includes labor, equipment, and materials, FY77 dollars

*All wood and masonry structures
**Derived from 6-year maintenance and repair project averages

Table 2

Corrosion-Related Project Totals (non-MCA)
for the Presidio of San Francisco

| Fiscal Year | Total Contract $ Volume | Corrosion-Related Value |
|---|---|---|
| 70 | 1,840,759 | 268,146 |
| adjusted for inflation* | 2,959,320 | 431,088 |
| 71 | 1,436,105 | 84,755 |
| adjusted for inflation* | 2,085,085 | 123,056 |
| 72 | 1,926,862 | 150,936 |
| adjusted for inflation* | 2,444,109 | 191,453 |
| 73 | 1,230,133 | 159,058 |
| adjusted for inflation* | 1,428,234 | 184,672 |
| 74 | 1,139,478 | 162,602 |
| adjusted for inflation* | 1,231,011 | 175,663 |
| 75 | 3,076,278 | 72,882 |
| Totals (adjusted) | 13,224,037 | 1,178,814 |

Overall average: 8.9%

*Adjusted by comparing Engineering News-Record Construction Cost Indexes for respective years, using FY 75 (December) as a baseline. Costs are multiplied by ratio of FY 75 index to fiscal year index in question.

leaching of zinc. Zinc die-cast handles failed either from galvanic action with the brass or steel valve stem, or by intergranular attack. These failures can be abated by prohibiting zinc and beta-brass components in applications which require superior longevity. Coppers, high copper alloys, or red brasses should be used for areas experiencing dealloying of zinc.

Copper and galvanized steel were used for all aboveground pressurized piping. Although plastic piping is corrosion resistant to most waters, its use was restricted to underground waste distribution systems. Reasons cited for not using plastic pipe aboveground were (1) brittleness caused by its exposure to sunlight, (2) the high coefficient of expansion, and (3) insufficient durability during a fire. Plastics used in underground piping were acrylonitrile-butadiene styrene (ABS) and polyvinyl chloride (PVC). Personnel were concerned about the shelf life and long setting times of ABS adhesives, and ABS piping had reportedly been chewed through by rats. PVC pipe had not been penetrated.

The Repairs and Utilities TM 5-551K, *Plumbing and Pipefitting*, was not used as a primary source of technical direction for maintenance actions. Rather, a "national" code was used, although several codes claim universal status.[2-5] TM 5-810-5 requires that initial system design comply with the *Uniform Plumbing Code* of the International Association of Plumbing and Mechanical Officials, but TM 551K does not specify a national code for maintenance actions. The national codes should be referenced in TM 5-551K and supervisory personnel directed to obtain copies (at Government expense) of the prevalent code in their region. These "national" codes usually are more progressive than local codes and allow use of more modern materials, since they are revised annually.

*Exterior Sheet Metal Work*

Galvanized steel roofing was not extensively used throughout the installation. Because roofing is either clay tile or built-up asphalt layers on a wood base, deterioration of exterior sheet metal was confined to guttering. Aluminum gutters developed pits caused by accumulated salt fall, and plastic gutters degraded after prolonged exposure to sunlight. Many of the plastic gutters cracked when ladders were

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2 *Uniform Plumbing Code* (International Association of Plumbing and Mechanical Officials, 1976).

3 *Standard Plumbing Code* (Southern Building Code Congress International, 1976).

4 *National Standard Plumbing Code* (National Association of Plumbing-Heating-Cooling Contractors, 1976).

5 *BOCA Basic Plumbing Code* (Building Officials and Code Administrators International, 1976).

placed against them, presenting a safety hazard. The galvanized guttering, whether original or replaced, was not specified with any minimal zinc thickness.* The ASTM A525 G90 Commercial Zinc Coating class should be used as a minimum (0.90 oz/sq ft [275 $g/m^2$]) requirement. Hot-dipping of formed sheets with zinc coatings ranging from 1.15 to 2.35 oz/sq ft (351 to 717 $g/m^2$) in the triple-spot test[6] may be necessary for areas experiencing severe degradation, since forming sheets will cause flaking of the thick zinc coatings. The base metal should be a copper bearing steel, 0.2 percent copper minimum.[7]

Another problem involving metal work was the constant need to replace galvanized vent stacks. Because these vents are exposed to heated furnace exhaust gases, they have an average life span of 5 to 8 years in the salty air. A superior metal for long-life applications would be commercially pure titanium in the fully annealed condition for formability. Unlike the thin gauge galvanized steel, the titanium would resist both the oxidative effects of heated gases and chloride attack. For vent stacks requiring shorter life with less chloride exposure, TT-P-38 Ready-Mixed Aluminum Paint applied to galvanized steel is suitable for temperatures up to $300^\circ F$ ($149^\circ C$). For temperatures beyond $300^\circ F$ ($149^\circ C$), TT-P-28 Heat Resisting Aluminum Paint is indicated.

*Building Hardware*

The use of zinc-chromated steel lock hardware or an unchromated varnished steel causes a major problem at this location. Typical life of this hardware is 5 to 8 years. A similar situation exists for steel butt hinges exposed to salt air. Door closers also have a reduced life, caused mainly by internal moisture accumulation. An all-brass lock has a typical life span of 16 years at the Presidio. However, many of the so-called "all-brass" locks (passage, dead bolt, anti-jimmy) supplied by the General Services Administration (GSA) contained steel parts, especially where strength was a requisite. This can be a worse situation than one in which the components are all-steel because the manufacturer has substituted steel for critically-stressed parts. Steel corrodes at

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* NOTE: CE 220.08, General Sheet Metalwork, does not permit selection of galvanized gutters. For "corrosion locations," this specification selects copper or copper-clad stainless. However, the copper-clad stainless is so thin (0.015 in. [.3310 mm]) that any discontinuities in the thin copper cladding would lead to severe pitting where salt fall occurred, such as at the Presidio.

6 ASTM Standard A525-75, *Annual Book of Standards* (Part 3) American Society for Testing and Materials (1976)

7 F. LaQue, "Corrosion Testing," *Proceedings of ASTM*, Vol 51 (1951), pp 495-582.

1 to 2 mpy (0.025-0.05 mm/yr) compared with 0.021 mpy ($5.25 \times 10^{-4}$ mm/yr) for cartridge brass, [8,9] not taking galvanic action into account.

*Refrigeration-Related Components*

Aluminum framing for dust filtration of intake air was badly pitted, and in several cases, completely corroded through. Dust filters accumulate the salt-laden air, and eventual evaporation concentrates the salt, resulting in a very saline dew. When a new hospital complex suffered framing failure after only 2 years, Facility Engineer personnel attempted to replace the framing with austenitic stainless steel, but evidently received a ferritic or martensitic grade (personnel stated the material was magnetic). This is an example of material substitution granted by nontechnical purchasing agents. In this location, a copper-nickel alloy (67 percent Ni, 33 percent Cu) would probably sustain less pitting in creviced areas than stainless steel.

Difficulties were also reported with rapid deterioration of aluminum evaporator and condenser fins, especially when coupled to copper tubing. "Spine" fins were also severely degraded. In general, these fins could not be brushed and should be prohibited in saline exposures. All-copper fins and tubing are mandatory for this location.

*Electrical Distribution Systems*

The principal difficulty at this site was the high resistance caused by corrosion at aluminum conductor drop lines which lead to the main circuit-breaker panel. The aluminum service drop at the weather head apparently accumulates moisture and overheats because of section loss or shorts. Neither the manufacturer of the weather head nor the type of wire insulation is known.

Another difficulty was caused by the failure to install ground rods when cast iron water mains were replaced with plastic. This left the seemingly grounded cold water pipe in a state where current may not drain away, depending on soil moisture conditions and the depth of the steel-plastic joint.

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[8] H. Copson, "Long-Time Atmospheric Corrosion Tests on Low-Alloy Steel," *Proceedings of ASTM*, Vol 60 (1960), pp 650-665.

[9] C. Hummer, C. Southwell, and A. Alexander, "Corrosion of Metals in Tropical Environments -- Copper and Wrought Copper Alloys," *Materials Protection*, Vol 7, No. 1 (1968), pp 41-47.

*Electrical Distribution Systems, Exterior*

The principal corrosion problems in these systems are corrosion of aluminum conductor/steel-reinforced (ACSR) and copper conductor splices and the deterioration of transformer cases.

Electricians at the Presidio use two types of connectors to join aluminum to copper. In the first method, a compression connector (with conductive grease) joins the aluminum to a copper pigtail, which then connects with a split bolt joining the copper cable. Split bolts are never retightened because of the danger of exceeding the flow stress where relaxation will occur; rather, they are simply replaced. The second connector is a wedge-shaped compression device which joins the cables by explosive force, requiring a powder-actuated tool. Its superiority in this environment may stem from permanent seizing induced by friction heating and extremely high compressive stresses at points of sliding impact. (See Figure 1 for details on this connector.) The use of compression-type splices in humid and saline areas should be emphasized in TM 5-680C. However, various proprietary connectors must be compared in several humid locations under monitored conditions of amperage, temperature, and dew point, before any particular connector can be endorsed.

Transformer cases require frequent repainting because of salt air and dew accumulation. In several instances, actual penetration through the case occurred. Since it is difficult to completely remove products without reducing case thickness, an economical coating system would be TT-P-615 Basic Lead Silico Chromate Primer Coating, Type I (Oil) or Type V (Oil & Alkyd), with a TT-E-522 Lustreless Phenolic Enamel, which has good resistance in humid seacoast areas. For extremely corrosive locations, use of MIL-P-38336 Inorganic Zinc Dust Primer and MIL-C-38427 Urethane or Epoxy Top Coating is indicated, although this coating system requires more careful surface preparation.

*Other Systems*

Leakage of raw water from heat exchangers was thought to contaminate boiler condensate. Conductivity should be tested periodically to determine if such a condition exists. Conductivity monitoring might be considered for new construction at key system locations. Inability to treat the water for low pressure boilers was also reported, as was damage to sodium silico fluoride injectors used for fluoridation of

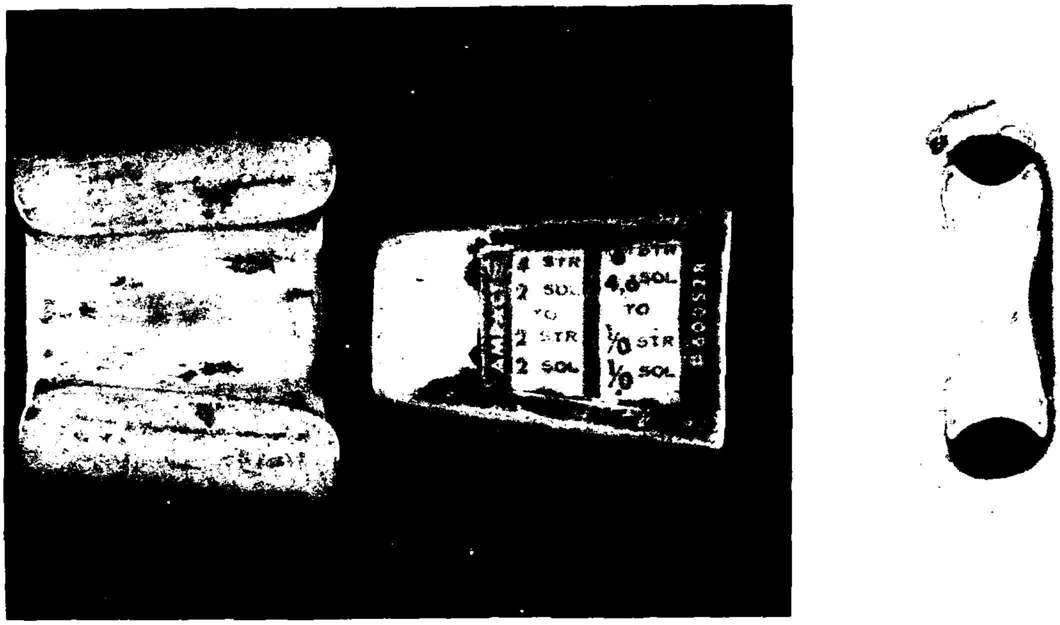

Figure 1. Powder-actuated compression-type fastener. Heat generated from friction, combined with mechanical seizing, may account for reported longevity of this connector. Conductive grease is also used.

drinking water. A suggested alloy for these injectors is Monel 200* (67 percent nickel, 31.5 percent copper, 1.25 percent iron), which has good resistance to any hydrofluoric acid (HF) which may form.[10] Another alternative is AISI 316, which has good resistance to hydrofluosilicic acid ($H_2S_iF_6$), although pitting may develop.[11]

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* "Monel 200" is a proprietary alloy manufactured by Huntington Alloys. Monel indicates a 67 percent Ni 33 percent Cu nominal composition. In addition, The American Water Works permits Hastelloy, rubber linings and several inert plastics like Teflon and polyethylene (F. Maier, "Fluorides in Water," *Water Quality & Treatment*, McGraw Hill, 1971).

11 R. Swandby, "Nickel Base Alloys," *Corrosion Resistance of Metals and Alloys*, ASC Monograph 158 (Reinhold, 1963), pp 522-524.

10 C. Paul and J. Moran, "Stainless Steel," *Corrosion Resistance of Metals and Alloys*, ASC Monograph 158 (Reinhold, 1963), pp 393-394.

# 3 FACILITY LIFE-CYCLE MAINTAINABILITY

Certain organizational impediments to effective corrosion control found at the Presidio were also typical of problems encountered at other Army installations.

## Maintainability of Construction

The District Engineer is responsible for the timely completion of a Military Construction project, keeping a close watch on cost growth, whereas the Facility Engineer is more concerned with maintainability. These goals may not necessarily be convergent. A continual, positive interplay must exist between the District and Facility Engineers so that new construction does not repeat the errors of the past. Both short- and long-term information regarding facility maintainability problems discovered after acceptance can significantly contribute toward improved construction. Long-term feedback is particularly important since corrosion problems often surface many years after the facility has been in use.

Both the Army and the Air Force have various *short-term* construction deficiency reporting mechanisms, but there is no *life-cycle* deficiency reporting system at present. A life-cycle reporting system proposed by the Directorate of Facilities Engineering (DAEN-FEM), OCE, suggests that recommendations for facility improvements be forwarded to major commands rather than the District.[12] However, corrosion is a region-specific phenomenon, and therefore is better controlled through on-going dialogue between the District and Facility Engineers. This dialogue could be accomplished by having the Facility Engineer submit an annual consolidated installation summary of facility maintainability trends (regardless of facility age) to the District, with information copies to OCE and major commands.

The advantages of a regional life-cycle reporting system are multiple, especially for corrosion problems. A regional system avoids universal adoption of specific materials, products, or procedures (minimizes manufacturer endorsement problems). A cost comparison of alternate materials could be taken into account, since prices vary depending on source of manufacture and shipping rates. Historical precedents for specification of a successful material would be provided *for a particular region*, and would be grounds for rejection of other materials because of their documented failure in certain applications.

[12] DAEN-FEM message dated 012106Z Dec 76; Subj: Interim Change, AR 420-10: Construction Improvement Recommendation.

Material Substitutions and Intended Facility Life

The superior material for a given application is one that has sufficient corrosion resistance which complements its mechanical or other required properties. However, other materials may be substituted during procurement, especially when acquisition price is the determining factor, and not the corrosion rate or long-term cost. This is particularly applicable to bench stock replacement items which are not subject to rigid material specifications. Although the lot-priced item seems equivalent and apparently less expensive, over the long run these components may have to be replaced several times, involving installation and procurement costs. Since corrosion rates vary with location, determining the cost effectiveness of replacement component parts may take several years. This can be accomplished by noting demand levels for various items over the years, or studying specific high replacement items in designated buildings, and noting differences in lifetimes of parts of generic equivalence.

Inferior materials are often used on buildings and structures which are kept long beyond their intended lifetime. In many cases, there is no rigid disposal schedule. If intended facility life is short, there is reluctance to use a superior material. This attitude persists because of the advanced physical age of many Army facilities. However, if labor force levels are reduced in the future, components must have a longer life since personnel may not be available to replace the shorter-life component.

## 4 CONCLUSIONS

1. The Facility Engineer of the Presidio allocates about 10.5 percent of his resources to corrosion-related work, including preventive maintenance, repair, and replacement actions.

2. Approximately 8.9 percent of all non-MCA Presidio maintenance and repair contracts are the result of corrosion. This percentage was obtained by adjusting prior year corrosion costs for inflation, adding them, and then dividing by total adjusted maintenance and repair contract values for the 6-year period analyzed.

3. Underground piping and potable water distribution systems incurred substantial losses. Atmospheric deterioration of exterior metal components was due to airborne salt fall.

4. Dealloying of thin-wall brass fixtures and failures of zinc die cast handles were common occurrences.

5. Although galvanized steel was used extensively, no attention was paid to zinc coating thickness specification.

6. Coated steel locks and hinges required frequent replacement because of corrosion. This problem was compounded by the inability to obtain the required all-brass components from GSA.

7. Aluminum condenser and evaporator fins deteriorated rapidly, decreasing heat transfer efficiency. Pitting, crevicing, and generalized attack occurred, especially with aluminum fins on copper tubing.

8. The corrosion of aluminum conductors joined to copper caused difficulties for electricians.

9. Formal mechanisms to provide feedback between the design agency and the inheriting maintenance organization on long-term corrosion-related deficiencies do not exist.

## 5 RECOMMENDATIONS

1. Closer controls should be placed on stocking the proper replacement parts for specific buildings, especially considering intended lifetime. It is not recommended that the best alloy always be used, but rather that a superior alloy or material be designated only for buildings that will require long-term service. This implies stocking multiple types of a generic item.

2. It is recommended that life-cycle cost rather than initial cost be considered. The life-cycle cost can be roughly indicated by watching demand levels on specific replacement parts over a period of years.

3. A facility deficiency reporting system which feeds long-term system life information back to the District from the Facility Engineer should be considered for adoption. This will permit formal dialogue between construction and maintenance forces, and will provide the District with design information regarding facility maintainability.

4. Several sections of TM 5-551K (AF TO 40P-1-1-31) and TM 5-680C should be revised in accordance with the recommended changes listed in Appendices A and B.

APPENDIX A:

RECOMMENDED CHANGES TO TM 5-551K

| RECOMMENDED CHANGES TO PUBLICATIONS AND BLANK FORMS<br>For use of this form, see AR 310-1, the proponent agency is the US Army Adjutant General Center. | Use Part II for Repair Parts and Special Tool Lists (RPSTL) and Supply Catalogs Supply Manuals (SC/SM) | DATE<br>29 Jun 1977 |
|---|---|---|
| TO: (Forward to proponent of publication or form) (Include ZIP Code)<br>Commandant<br>US Army Engineer School<br>Fort Belvoir, VA 22060 | FROM: (Activity and location) (Include ZIP Code)<br>US Army Construction Engineering Research Laboratory<br>Champaign, IL 61820 | |

PART I - ALL PUBLICATIONS (EXCEPT RPSTL AND SC/SM) AND BLANK FORMS

| PUBLICATION/FORM NUMBER | DATE | TITLE |
|---|---|---|
| TM 5-551K (AF TO 40P-1-131) | July 1971 | Plumbing and Pipefitting |

| ITEM NO. | PAGE NO. | PARA-GRAPH | LINE NO.* | FIGURE NO. | TABLE NO. | RECOMMENDED CHANGES AND REASON (Exact wording of recommended change must be given) |
|---|---|---|---|---|---|---|
| 1. | 4-1 | 4-1a(1) | 6 | | | Delete "where liquids may corrode or". Add: "For handling acidic corrosives, high silicon (14%) cast iron should be used. For strong caustics under pressure, use monel or nickel-bearing austenitic stainless steels." REASON: Unless a rigorous cost analysis and provisions to replace the cast iron pipe are made, high silicon cast iron has marked corrosion resistance to strong acids compared to gray cast iron. It will handle most alkalies well, except for stress corrosion cracking due to caustic embrittlement. The nickel-base alloys and higher nickel austenitic stainless steels will tolerate high causticity under stress. |
| 2. | 4-8 | 4-18 | | | | Add: Place asterisks on ground joint union caption and flange union caption. Add to Figure 4-18 description: "*Also available with dielectric gaskets and bolt sleeves for coupling dissimilar metals; similarly, dielectric ground joint unions are also manufactured." REASON: Availability of this fitting variation should be made known to decrease galvanic corrosion of pipe junctions in corrosive media. |
| 3. | 4-16 | 4-23b | 3 | | | Delete "will not rust, rot or corrode." Insert "is not corroded by most natural and treated waters. Some plastics are susceptible to degradation by certain strong acids, organic solvents and sunlight. They are also subject to embrittlement at freezing temperatures." REASON: Statement is too general and misleading to the uninformed reader regarding limitations of generic plastics. Plastics, like metals, are environment-sensitive and should not be thought of as a cure-all for corrosion problems. There are circumstances where plastics will "rot and corrode." |

*Reference to line numbers within the paragraph or subparagraph.

| TYPED NAME, GRADE OR TITLE | TELEPHONE EXCHANGE/AUTOVON, PLUS EXTENSION | SIGNATURE |
|---|---|---|
| CHRISTOPHER HAHIN<br>Corrosion Metallurgist | (217) 352-6511, Ext 216 | Christopher Hahin |

**DA FORM 1 FEB 74 2028** REPLACES DA FORM 2028, 1 DEC 68, WHICH WILL BE USED.

| RECOMMENDED CHANGES TO PUBLICATIONS AND BLANK FORMS<br>For use of this form, see AR 310-1; the proponent agency is the US Army Adjutant General Center. | Use Part II (reverse) for Repair Parts and Special Tool Lists (RPSTL) and Supply Catalogs/Supply Manuals (SC/SM). | DATE |
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| TO: (Forward to proponent of publication or form) (Include ZIP Code)<br>(CONTINUATION) | FROM: (Activity and location) (Include ZIP Code) | |

PART I - ALL PUBLICATIONS (EXCEPT RPSTL AND SC/SM) AND BLANK FORMS

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| TM 5-551K (AF TO 40P-1-131) | July 1971 | Plumbing and Pipefitting |

| ITEM NO. | PAGE NO. | PARA-GRAPH | LINE NO.* | FIGURE NO. | TABLE NO. | RECOMMENDED CHANGES AND REASON (Exact wording of recommended change must be given) |
|---|---|---|---|---|---|---|
| 4. | 10-4 | | | | 10-4 | Add as a note to Table 10-4: "Water velocities above 7 feet per second in copper piping may result in internal erosion corrosion damage." |
| 5. | 12-3 | 12-5c | 10 | | | Add to para C: "For buried sections of gas pipe that have cathodic protection applied, protected areas may require wire jumpers to maintain continuity, bypassing the higher resistance Dresser coupling." |
| 6. | 10-8, 10-9 | 10-8 | | | | REASON: This paragraph requires complete revision. Several corrosion mechanisms are incompletely explained and other forms of corrosion that plumbers encounter (besides galvanic and general attack) are not mentioned. There are more ways of combatting corrosion than the two methods listed. The explanation of galvic corrosion on the basis of different electrical conductivity is confusing. Galvanic differences usually stem from inherent metallic stability or formation of adherent surface films. For example, titanium has poor IACS conductivity, but has far superior performance in salt water than iron (a fair electrical conductor). The description of corrosion as a replating process in piping may hold for the dealloying of brass, but in most cases the iron forms an insoluble corrosion product. Oxygen content, pH, and velocity effects are not discussed. Impressed-current cathodic protection, superior alloy section and liner materials are not mentioned as additional preventive methods. SUGGESTED REVISION: "a. Corrosion is the degradation of a material or alloy by its environment. Plumbers replace large quantities of pipe because of corrosion, especially in buried and above ground water supply piping. Several forms of corrosion are encountered by plumbers besides uniform attack, which results in thinning of pipe walls. |

*Reference to line numbers within the paragraph or subparagraph.

| TYPED NAME, GRADE OR TITLE | TELEPHONE EXCHANGE/AUTOVON, PLUS EXTENSION | SIGNATURE |
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| ITEM NO. | PAGE NO | PARAGRAPH | LINE NO * | FIGURE NO | TABLE NO | RECOMMENDED CHANGES AND REASON (Exact wording of recommended change must be given) |
|---|---|---|---|---|---|---|

These other forms of corrosion are (1) galvanic attack, (2) pitting, (3) crevice corrosion, (4) erosion corrosion, (5) dealloying, (6) intergranular corrosion and (7) stress corrosion.

(1) The uniform corrosion of steel increases when the amount of oxygen, the temperature, and the acidity increase. Since most potable water is not highly acidic, pHs less than 4 would be found mostly in undrinkable process water.

(2) Galvanic attack occurs when two different metals are mated by threads or flanges. The severity of the corrosion depends on how the two metals behave in water or soils. How long a dissimilar joint will last can be roughly predicted by a galvanic series. The greater the separation of each metal on the series, the more likely galvanic corrosion will take place. A rougn galvanic series for common plumbing alloys is as follows:

| | |
|---|---|
| inactive metals | Gold, silver |
| | Titanium |
| | Stainless steels (austenitic) |
| | Nickel alloys |
| | Bronzes |
| | Copper and brass |
| | Tin |
| | Lead |
| | Cast iron |
| | Mild steel |
| | Aluminum alloys |
| | Cadmium |
| | Zinc |
| active metals | Magnesium |

This is avoided by dielectric fittings or by changing materials.

*Reference to line numbers within the paragraph or subparagraph.

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|---|---|---|---|---|---|---|
| | | | | | | (3) Pitting occurs when corrosion takes place in a small area, and the surrounding area is not corroded. This may be caused by the inherent tendency of the alloy to pit in certain corrosives, or by contaminants that may settle, inducing pits. Stainless steels, magnesium, aluminum and zinc tend to pit. Since it is usually more difficult to change environment, it is best to substitute a material that does not pit. |
| | | | | | | (4) Crevice corrosion occurs when conditions in the piping system are not uniform, usually caused by the piping design. Gaskets are common places where oxygen is partially excluded, but water is not. Gaskets with a wicking action (porous) often suffer crevice corrosion. Improperly welded seams which do not completely seal out moisture are also susceptible. |
| | | | | | | (5) Erosion corrosion occurs when the velocity of the water exceeds a certain critical value. The metal cannot replace its protective film because it is being swept away. Copper is especially susceptible to erosion corrosion. Recommended ways to stop the gully-like attack of erosion corrosion are to reduce pressure, increase pipe diameter or eliminate sharp bends. Substitution of steel may be necessary. |
| | | | | | | (6) Dealloying is a form of corrosion that is usually found in brass or cast iron. In brass alloys, the zinc leaches out leaving a weak spongy copper (dezincification). For gray cast iron, the iron (ferrite) corrodes out, leaving just graphite (graphitization). To prevent dezincification, use of brasses with more than 70% copper should reduce the problem. Neither ductile nor malleable iron will suffer graphitization like gray cast iron. |

*Reference to line numbers within the paragraph or subparagraph.

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| ITEM NO. | PAGE NO. | PARA-GRAPH | LINE NO.* | FIGURE NO. | TABLE NO. | RECOMMENDED CHANGES AND REASON |
|---|---|---|---|---|---|---|
| | | | | | | However, both ductile and malleable iron have a corrosion resistance similar to that of steel.<br><br>(7) Intergranular corrosion is [illegible] encountered by plumbers. [illegible] die cast [illegible] handles or [illegible] drain [illegible] corrode this way, becoming brittle. [illegible] alloys are susceptible. [illegible] the microscopic metal crystals [illegible] causing eventual rupture. [illegible] are preferable alloys for such cases.<br><br>(8) Stress corrosion is rarely encountered by plumbers, and is usually a problem in [illegible] potable water or other process piping under pressure. Stress corrosion cracking [illegible] action of a specific corrosive on [illegible] when piping is under pressure. An example [illegible] surized brine contained by stainless steel [illegible] brass in contact with ammonia. Not all metals behave the same when subject to pressurized corrosives; some are more resistant than others. Stress-corrosion cracking takes place fairly quickly, from several days to a few [illegible] sult with engineering personnel if you [illegible] this form of corrosion to be a problem.<br><br>(9) Several methods are available at the plumber's discretion to solve corrosion [illegible]. He may change the material during replacement of the piping to one more suited for the environment. He may alter the configuration (but not inter- fering with operation) by increasing the diameter or changing bend severity. If excessive air is being drawn into the system, he may exclude it or recommend that the pH be changed at its source. If drinking water is involved, changes must not [illegible] any detrimental effects on public health. [illegible] |

*Reference to line numbers within the paragraph or subparagraph.

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|---|---|---|---|---|---|---|
| | | | | | | lined with inert or protective coatings, like glass, teflon, or zinc, may be used. For lines that are buried, he should verify whether cathodic protection is being applied. This includes the replacement of magnesium anodes in water heaters, and the operation of both sacrificial (magnesium or zinc packaged anodes) and impressed-current (rectifier) cathodic protection systems on buried mains and laterals.<br><br>(10) For more detailed information about corrosion, see TM 5-811-4, *Corrosion Control* and Military Standardization Handbook MIL-HDBK-721 (MR), *Corrosion and Corrosion Protection of Metals*. Another good general reference is *Corrosion Engineering*, by Fontana and Greene." |
| 7 | 10-9 | 10-8c(3) | | | | Add: "Severe scaling in a water main should be reported to main water plant personnel. Thin unbroken scale is beneficial and prevents corrosion by forming a protective layer." |
| 8 | A-1 | | | | | Add new paragraph: "A-4. Standardized Plumbing Codes. *Uniform Plumbing Code*, International Association of Plumbing and Mechanical Officials, Los Angeles, latest edition. *Standard Plumbing Code*, Southern Building Code Congress International Birmingham, latest ediction. *National Standard Plumbing Code*, National Association of Plumbing-Heating-Cooling Contractors, Washington, D.C., and Encino, CA, latest edition. *BOCA Basic Plumbing Code*, Building Officials and Code Administrators International, Inc., Chicago, latest edition." |

*Reference to line numbers within the paragraph or subparagraph.

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APPENDIX B:

RECOMMENDED CHANGES TO TM 5-680C

PRECEDING PAGE NOT FILMED BLANK

| RECOMMENDED CHANGES TO PUBLICATIONS AND BLANK FORMS<br>For use of this form, see AR 310-1; the proponent agency is the US Army Adjutant General Center. | [illegible] | DATE<br>29 Jun 1977 |
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| TO: (Forward to proponent of publication or form) (Include ZIP Code)<br>Commandant<br>US Army Engineer School<br>Fort Belvoir, VA 22060 | FROM: (Activity and location) (Include ZIP Code)<br>US Army Construction Engineering Research Laboratory<br>Champaign, IL [illegible] | |

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| TM 5-680C | Sep 63 | Overhead Distribution Systems |

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|---|---|---|---|---|---|---|
| 1 | 47 | 31 | 16 | | | Insert the following after ". . . conditions." "Powder-actuated compression connectors which have comparable performance are also available (see Figure 56)." REASON: Superior performance of this type of connector has been reported by field personnel. Such connectors perform markedly better than split bolts in humid or marine areas. |
| 2 | 47 | 31 | | | | Add new paragraph: "c. Compression connectors are recommended for splicing and tapping in humid or marine regions. It is critical that the junction, especially if aluminum is being connected, have sufficient anti-oxidant conductive grease to exclude moisture, dew, or salt accumulation. Many splices have prefilled grease containers which uniformly seal the junction upon compression, whereas others require the electrician to coat mating surfaces with antioxidant grease before tightening the joint." |
| 3 | 47 | | | 56 | | Replace split bolt photograph with one of powder-actuated wedge connector. REASON: Since shape of split bolts is well known, the superior and less familiar connectors should be shown. |

* Reference to line numbers within the paragraph or subparagraph.

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| CHRISTOPHER HAHIN<br>Corrosion Metallurgist | (217) 352-6511, Ext 216 | Christopher Hahin |

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Effects of corrosion on military facilities of the Presidio of San Francisco. -- Champaign, IL : Construction Engineering Research Laboratory ; Springfield, VA : available from National Technical Information Service , 1978.
24 p. : ill. ; 27 cm. (Interim report -- Construction Engineering Research Laboratory ; M-254).

1. Corrosion and anti-corrosives. 2. Presidio of San Francisco, CA. I. Title. II. Series: U.S. Construction Engineering Research Laboratory. Interim report ; M-254.